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NOVEL 1,3,5-TRIS(ARYLAMINO)BENZENES

Field of the Invention

This invention relates to novel 1,3,5-tris(arylamino)-benzenes useful as organic semiconductors. More particularly, the invention relates to novel 1,3,5-tris(arylamino)benzenes that are superior in reversibility of oxidation-reduction process and can form stable organic semiconductor film readily by a coating method or a vacuum deposition method. Accordingly they are suitable for use as organic semiconductors in a variety of electronic devices such as electric charge transport agents in electrophotographic devices or organic semiconductors in solar batteries.

Background Art

In recent years, organic semiconductors comprised of amorphous film of organic substances are in wide use in a variety of electronic devices. For example, an organic amorphous film is formed by preparing a coating composition comprised of a binder resin such as polycarbonate resin and a low molecular weight organic compound such as a triphenylamine derivative having photoelectric function dissolved in a suitable organic solvent and then by coating and drying the composition. The film thus formed is used as a positive hole transport layer in electrophotographic devices, as described in JP-A-1999-174707. Similarly, an organic amorphous film is formed by preparing a coating composition comprised of a so-called star-burst compound dissolved in a suitable organic solvent and then by coating and drying the composition. The film thus formed is used as an organic p-type semiconductor film in solar batteries, as described in JP-A-2000-

174657.

As described above, organic semiconductor films comprised of organic amorphous film have been prepared by preparing a coating composition using a low molecular weight organic compound having photoelectric function together with a binder resin and then coating the composition on a suitable substrate and drying the composition. However, many of the low molecular weight organic compounds that have hitherto been known have low oxidation potentials, and accordingly when they are formed to organic semiconductor films by a coating method, they are easily oxidized, so that it is not easy to form a film using such low molecular weight organic compounds. They have also no sufficient reversibility in oxidation-reduction process so that it is difficult to prepare organic semiconductor film durable and suitable for practical use. In addition, the resulting organic semiconductor films have no sufficient heat resistance and hence the electronic devices using such organic semiconductor films are inferior in stability and durability.

As typical low molecular weight organic compounds that have photoelectric function and are usable for preparing organic semiconductor films, there have been known such compounds as N,N,N',N'-tetramethylbenzidine, N,N,N',N'-tetraphenyl-(1,1'-biphenyl)-4,4'-diamine, N,N'-diethyl-N,N'-diphenyl-(1,1'-biphenyl)-4,4'-diamine, or N,N,N',N'-tetra(3-methylphenyl)-4,4'-diaminostilbene. However, these low molecular weight organic compounds form only amorphous films that are by themselves not so stable as to be used as electric charge transport agents in organic photosensitive elements. Accordingly, they are dispersed in a binder resin (that is, diluted with a binder resin), and the resulting dispersion is applied to a substrate to form an amorphous film.

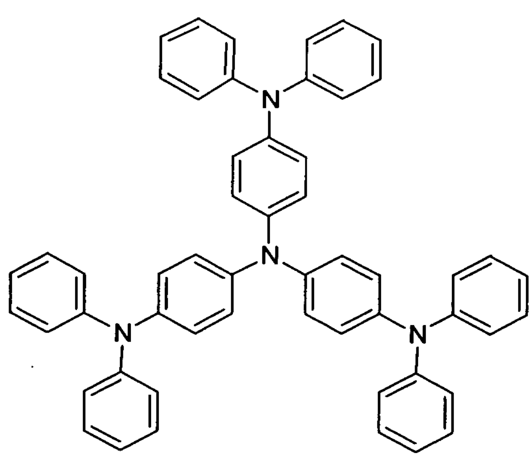
Thus, the known low molecular weight organic compounds that form an organic amorphous film are diluted with a binder resin and are influenced by the binder resin which forms a matrix for the amorphous film so that the organic amorphous film cannot

exhibit sufficiently the properties that they originally possess. In addition, if the known low molecular weight organic compounds form an amorphous film that is relatively stable at normal temperatures with the aid of a binder, they have low glass transition temperatures so that the film is poor in heat resistance and is not suitable for practical use.

Accordingly, the development of low molecular weight organic compounds that have photoelectric conversion function and are capable of forming amorphous film by themselves at normal temperatures or higher has been pushed on with in recent years, and as results, some nitrogen-containing polynuclear aromatic compounds called star-burst molecules have been proposed as such low molecular weight organic compounds.

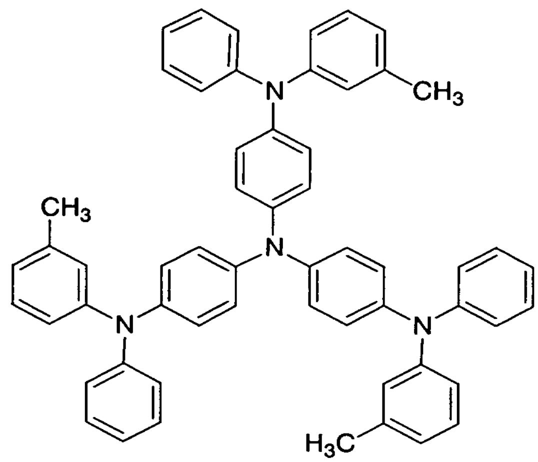
The star-burst molecules are divided into three groups based on their molecular structures: compounds having triphenylamine structure (triphenylamines), compounds having triaminobenzene structure (triaminobenzenes) and compounds having triphenylbenzene structure (triphenylbenzenes). Beside the above-mentioned, compounds having triphenylmethane structure are also proposed.

The triphenylamines include, for example, 4,4',4"-tris-(N,N-diphenylamino)triphenylamine (TDATA) (1) having the structure



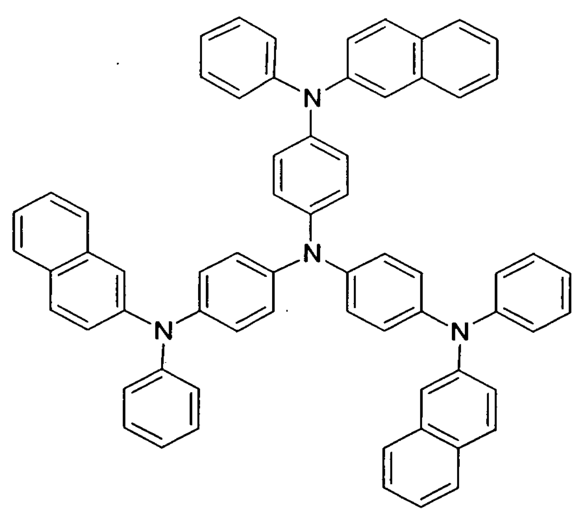
(1)

as described in JP-A-1990-224353; 4,4',4"-tris(N-phenyl-N-m-tolylamino)triphenylamine (m-MTDATA) (2) having the structure



(2)

as described in JP-A-1990-224353; 4,4',4"-tris(N-(2-naphthyl)-N-phenylamino)triphenylamine (2-TNATA) (3) having the structure



(3)

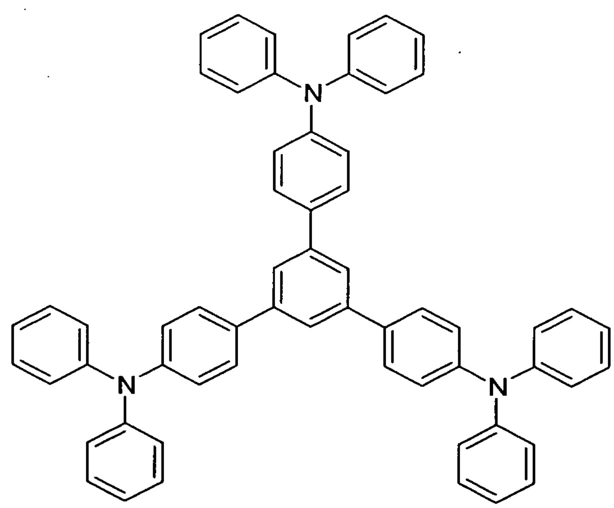
as described in JP-A-1996-291115; and 4,4',4"-tris(N-(1-naphthyl)-N-phenylamino)triphenylamine (1-TNATA).

These triphenylamines are reversible in oxidation-reduction process, however, they have low oxidation potentials (oxidation potential against Ag/Ag^+ electrode, the same hereunder) of about 0.1V or less so that there is a problem in that they are

easily oxidized when they are formed to organic semiconductor film by a coating method.

m-MTDATA has a glass transition temperature of about 77℃ so that it is difficult to use the compound in practical electronic devices, and on the other hand, 2- or 1-TNATA has a glass transition temperature of about 110℃ and is capable of forming heat-resistant organic amorphous film, but the compound is readily crystallized so that the resulting organic amorphous film is lacking in stability or durability.

The triphenylbenzenes include, for example, 1,3,5-tris(4-(N,N-diphenylaminophenyl)benzene (TDAPB) having the structure (4)



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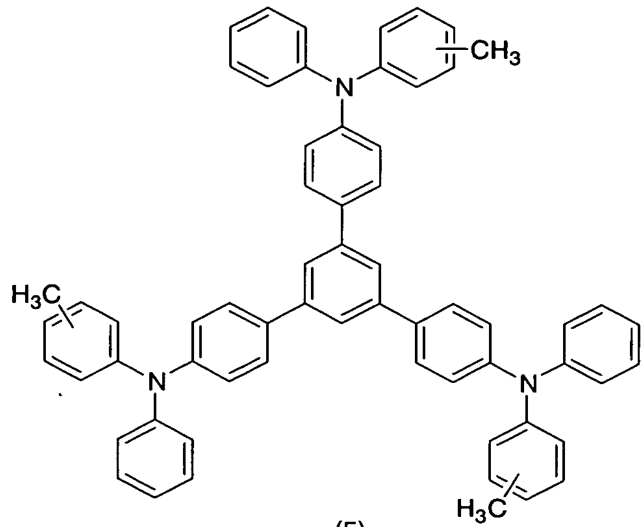
and 1,3,5-tris(4-(N-tolyl-N-phenylaminophenyl)benzene (MTDAPB) (5) having the structure

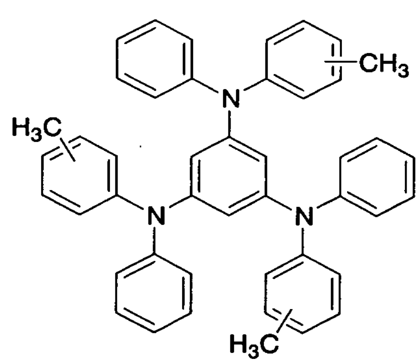


(5)

as described in Bando Technical Report, Vol. 2, pp. 9-18, 1998 (Bando Chemical Industries, Ltd.).

The triphenylbenzenes are capable of forming amorphous film and have oxidation potentials in the range of 0.6-0.7V, but they are irreversible in oxidation-reduction process so that they are not suitable for use in practical use as organic semiconductors.

In turn, the triaminobenzenes include, for example, 1,3,5-tris(N-methylphenyl-N-phenylamino)benzene (MTDAB) having the structure (6)



(6)

as described in Bando Technical Report, Vol. 2, pp. 9-18, 1998 (Bando Chemical Industries, Ltd.). The triaminobenzenes also have oxidation potentials in the range of 0.5-0.6V, but they are

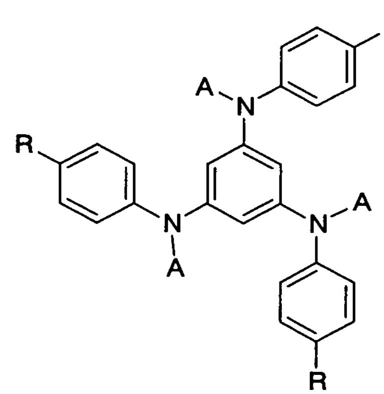
irreversible in oxidation-reduction process, like the above-mentioned triphenylbenzenes, and in addition, they have glass transition temperatures as low as about 60℃ or less so that they are not suitable for use in practical use as organic semiconductors. They have further problems in heat resistance.

The invention has been accomplished to solve the above-mentioned problems in the star-burst molecules having triaminobenzene structure for use as materials for organic semiconductors.

Accordingly, it is an object of the invention to provide novel 1,3,5-tris(arylamino)benzenes that have oxidation potentials in the range of about 0.5-0.6V and high glass transition temperatures and that are superior in reversibility in oxidation-reduction process and heat resistance so that they are readily formed to organic semiconductor film by a coating method or vacuum deposition method, as well as they are capable of forming stable and durable high-performance organic semiconductor film by themselves because they are capable of forming amorphous film by themselves with no aid of binder resins at normal temperatures or higher.

Summary of the Invention

The invention provides 1,3,5-tris(arylamino)benzenes represented by the general formula (I)



(I)

wherein A is naphthyl, anthryl, phenanthryl, biphenylyl or terphenylyl group, and R is alkyl having 1-6 carbon atoms or cycloalkyl group having five or six carbon atoms.

Brief Explanation of Drawings

Figure 1 is an infrared absorption spectrum of 1,3,5-tris-(N-(p-methylphenyl)-N-(1-naphthyl)amino)benzene (p-MTPNAB) of the invention;

Figure 2 is a differential scanning calorimetry (DSC) curve of 1,3,5-tris(N-(p-methylphenyl)-N-(1-naphthyl)amino)-benzene (p-MTPNAB) of the invention;

Figure 3 is a cyclic voltamogram of 1,3,5-tris(N-(p-methylphenyl)-N-(1-naphthyl)amino)benzene (p-MTPNAB) of the invention;

Figure 4 is a fluorescence spectrum of 1,3,5-tris(N-(p-methylphenyl)-N-(1-naphthyl)amino)benzene (p-MTPNAB) of the invention;

Figure 5 is an infrared absorption spectrum of 1,3,5-tris-(N-(p-tert.-butylphenyl)-N-(1-naphthyl)amino)benzene of the invention;

Figure 6 is a differential scanning calorimetry (DSC) curve of 1,3,5-tris(N-(p-tert.-butylphenyl)-N-(1-naphthyl)amino)-benzene of the invention;

Figure 7 is a cyclic voltamogram of 1,3,5-tris(N-(p-tert.-butylphenyl)-N-(1-naphthyl)amino)benzene of the invention;

Figure 8 is an infrared absorption spectrum of 1,3,5-tris-(N-(p-methylphenyl)-N-(4-biphenylyl)amino)benzene (p-MTPBAB) of the invention;

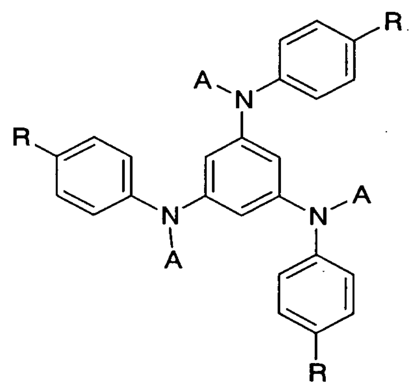
Figure 9 is a differential scanning calorimetry (DSC) curve of 1,3,5-tris(N-(p-methylphenyl)-N-(4-biphenylyl)amino)-benzene (p-MTPBAB) of the invention;

Figure 10 is a cyclic voltamogram of 1,3,5-tris(N-(p-methylphenyl)-N-(4-biphenylyl)amino)benzene (p-MTPBAB) of the invention; and

Figure 11 is a fluorescence spectrum of 1,3,5-tris(N-p-methylphenyl)-N-(4-biphenylyl)amino)benzene (p-MTPBAB) of the invention.

Best Mode for Carrying out the Invention

The 1,3,5-tris(arylamino)benzenes of the invention are expressed by the general formula (I)



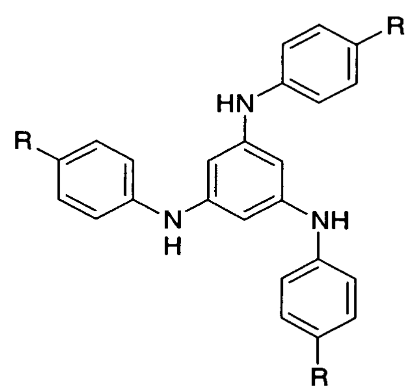
(I)

wherein A is naphthyl, anthryl, phenanthryl, biphenylyl or terphenylyl group, preferably 1- or 2-naphthyl, 1-, 2- or 9-anthryl, 1-, 2-, 3-, 4- or 9-phenanthryl, 2-, 3- or 4-biphenylyl, or 2-, 3-, 4- 2"- or 3"-terphenylyl group. In particular, it is preferred that A is 1- or 2-naphthyl, 9-phenanthryl, 4-biphenylyl or 4-p-terphenylyl group.

According to the invention, the naphthyl, anthryl, phenanthryl, biphenylyl or terphenylyl group may carry substituents thereon that give no harmful influence on oxidation potentials, reversibility of oxidation-reduction process or glass transition temperatures of the desired 1,3,5-tris(arylamino)-benzenes. Such substituents include, for example, alkyl groups, alkoxy groups, aryloxy groups, aralkyl groups, alkyl aryl groups, primary, secondary or tertiary amino groups, nitro groups, cyano groups or halogen atoms. However, it is preferred that 1,3,5-tris-(arylamino)benzenes of the invention have 1- or 2-naphthyl group or 4-biphenylyl group that carry no such substituents thereon.

Further according to the invention, in the 1,3,5-tris-(arylamino)benzenes represented by the general formula (I), R is an alkyl group of 1-6 carbon atoms or a cycloalkyl group of five or six carbon atoms, and more particularly, the alkyl group is methyl, propyl, butyl, pentyl or hexyl group. When the alkyl group has three or more carbon atoms, it may be either linear or branch. On the other hand, the cycloalkyl group is cyclopentyl or cyclohexyl group. However, R is preferably a methyl or tert.-butyl group.

The 1,3,5-tris(arylamino)benzenes of the invention is obtained by the reaction of 1,3,5-tris(p-alkylphenylamino)benzenes represented by the general formula (II)



(II)

wherein R is the same as the above with an aryl halide represented by the general formula (III)

A-X

(III)

wherein A is the same as above and X is a halogen atom, depending on the 1,3,5-tris(arylamino)benzene to be obtained, in the presence of a base and copper powder under an atmosphere of inert gas such as nitrogen, argon or helium using a crown compound such as 18-crown-6 (or 1,4,7,10,13,16-hexaoxacyclooctadecane) as a catalyst, if necessary, in a solvent.

The aryl halides preferably used are, for example, iodides or bromides. If necessary, chlorides are also used. By way of example, when 1,3,5-tris(N-(p-methylphenyl)-N-(1-naphthyl)-amino)benzene (p-MTPNAB) or 1,3,5-tris(N-(p-tert.-butylphenyl)-

N-(1-naphthyl)amino)benzene is to be obtained, 1-iodonaphthalene is preferably used as the aryl halide, and on the other hand, when 1,3,5-tris(N-(p-methylphenyl)-N-(4-biphenylyl)amino)benzene (p-MTPBAB) is to be obtained, 4-iodobiphenyl is preferably used as the aryl halide.

The aryl halides are used in excess in relation to 1,3,5-tris(p-alkylphenylamino)benzene. More particularly, the aryl halides are used preferably in an amount of more than three mole parts in relation to mole part of 1,3,5-tris(p-alkylphenyl-amino)benzene, and more preferably in an amount of 3-10 mole parts, and most preferably in an amount of 3.5-5 mole parts in relation to mole part of 1,3,5-tris(p-alkylphenylamino)- benzene.

The bases used in the reaction include, for example, hydroxides of alkali metals such as potassium hydroxide, or carbonates or hydrogen carbonates of alkali metals, especially those of sodium or potassium, and in particular, potassium carbonate is preferred. In the reaction, any solvent may be used so far as it does not inhibit the reaction, and usually hydrocarbon solvents such as decalin, mesitylene or heptane are preferably used. The reaction temperature is not specifically limited, but it is usually in the range of 140-190℃, and the reaction time is usually in the range of 5-30 hours.

After the completion of reaction, the reaction product is dissolved in an organic solvent and the catalyst used is separated by filtration, and then the reaction product is separated and purified by column chromatography using an appropriate eluate to provide a high purity product in high yields.

The 1,3,5-tris(arylamino)benzenes of the invention have oxidation potentials in the range of about 0.5-0.6V. From the structural point of view, in the first place, they have a skeleton of 1,3,5-tris(arylamino)benzene in which one of the substituents on each of nitrogen atoms is p-alkylphenyl group, so that the p-alkylphenyl substituent covers the active cite of the compound thereby securing the reversibility in oxidation-reduction process. In the second place, said each of nitrogen atoms carries naphthyl,

anthryl, phenanthryl, biphenylyl or terphenylyl group thereon as a substituent so that the compound has high glass transition temperatures and hence high heat resistance, and in addition, the compound has improved reversibility in oxidation-reduction reaction.

As described above, the 1,3,5-tris(arylamino)benzenes of the invention are suitably used for preparation of organic semiconductor film that is superior in stability and heat resistance. Furthermore, the 1,3,5-tris(arylamino)benzenes of the invention are capable of forming amorphous film by themselves at normal temperatures or higher, and hence they are capable of forming high-performance durable organic semiconductor film by themselves.

Accordingly, the 1,3,5-tris(arylamino)benzenes of the invention are suitably used as elements in various electronic devices such as charge transport agents in electrophotography or organic semiconductors in solar batteries, although they are not specifically limited in their use.

Example

The invention is described in more detail with reference to examples, however, the invention is not limited thereto.

Example 1

(Synthesis of 1,3,5-tris(p-tolylamino)benzene)

11.8 g of phloroglucinol, 50 g of p-toluidine and 0.5 g of iodine were placed in a 300 mL capacity three necked flask and the reaction was carried out at a temperature of 150℃ for 15 hours with stirring under a nitrogen atmosphere. After the reaction, the resultant reaction mixture was washed with methanol, hexane and methanol in this order, followed by drying to provide the desired 1,3,5-tris(p-tolylamino)benzene as slightly reddish solid. The yield was 86.5%.

(Synthesis of 1,3,5-tris(N-(p-methylphenyl)-N-(1-naphthyl)amino)-

benzene (p-MTPNAB))

2.0 g of 1,3,5-tris(p-tolylamino)benzene, 6.4 g of 1-iodo-naphthalene, 6.9 g of potassium carbonate, 1.0g of copper powder, 0.7 g of 18-crown-6 (or 1,4,7,10,13,16-hexaoxacyclooctadecane) and 15 mL of mesitylene were placed in a 100 mL capacity glass flask and the reaction was carried out at a temperature of 170℃ for 18 hours under a nitrogen atmosphere. After the reaction, the resultant reaction mixture was extracted with toluene and the toluene solution was subjected to silica gel chromatography to fractionate the reaction product. The reaction product was then purified by recrystallization and then by sublimation to provide 2.2 g of the desired 1,3,5-tris(N-(p-methylphenyl)-N-(1-naphthyl)-amino)benzene (p-MTPNAB). The yield was 57%.

Elemental analysis (%):

	C	H	N
Calculated:	88.68	5.88	5.44
Measured:	88.58	6.00	5.43

Mass analysis: $M^+=771$

Infrared absorption spectrum is shown in Fig. 1.

Differential scanning calorimetry (DSC):

About 5mg of p-MTPNAB was weighed as a sample, and it was melted in a differential scanning calorimetric device and cooled to room temperature at a rate of 50℃ per minute. The sample did not crystallized, but it became amorphous glass. Subsequently, the thermal characteristics of the sample were measured by heating at a rate of 5℃ per minute by using an aluminum plate as a reference. As the DSC chart is shown in Fig. 2, the compound was found to have a glass transition temperature (Tg) of 87℃ and a crystallization temperature (Tc) of 167℃.

Cyclic voltammetry (CV):

p-MTPNAB was dissolved in dichloromethane and the solution was arranged at a concentration of 10^{-3} M. The oxidation reduction characteristics of the sample were measured using tetrabutylammonium perchlorate ($(n\text{-}C_4H_9)_4NClO_4$ (0.1M)) as a supporting electrolyte and Ag/Ag^+ as a reference electrode at a scan

speed of 50mV/s. As the CV chart is shown in Fig. 3, the compound has an oxidation potential of 0.6V (vs. Ag/Ag^{+}). It was found that the compound had reversibility in oxidation reduction process after 50 times measurements, indicating that the compound is suitably used as organic positive hole transport agents.

Fluorescence spectrum:

A deposition film (an amorphous film) 500Å thick was prepared by using a vacuum deposition apparatus, and the film was subjected to measurement of fluorescence spectrum using excitation light of a wavelength of 320 nm. As the spectrum is shown in Fig. 4, the compound has an emission peak at 435.4 nm.

Example 2

(Synthesis of 1,3,5-tris(p-tert.-butylphenylamino)benzene)

4.0 g of phloroglucinol, 23.8 g of p-tert.-butylaniline and 0.2 g of iodine were placed in a 100 mL capacity three necked flask and the reaction was carried out at a temperature of 160℃ for 2.5 hours with stirring under a nitrogen atmosphere. After the reaction, the resultant reaction mixture was washed with hexane and then recrystallized from methyl ethyl ketone/ethanol, followed by drying to provide 7.4 g of the desired 1,3,5-tris(p-tert.-butylphenylamino)benzene as white solid. The yield was 44.7 %.

(Synthesis of 1,3,5-tris(N-(p-tert.-butylphenyl)-N-(1-naphthyl)-amino)benzene)

2.6 g of 1,3,5-tris(p-tert.-butylphenylamino)benzene, 6.4 g of 1-iodonaphthalene, 6.9 g of potassium carbonate, 1.0g of copper powder, 0.7 g of 18-crown-6 (or 1,4,7,10,13,16-hexaoxacyclooctadecane) and 20 mL of mesitylene were placed in a 100 mL capacity flask and the reaction was carried out at a temperature of 170℃ for 16.5 hours under a nitrogen atmosphere. After the reaction, the resultant reaction mixture was extracted with toluene and the toluene solution was subjected to silica gel chromatography to fractionate the reaction product. The reaction product was then purified by recrystallization and then by

sublimation to provide 2.8 g of the desired 1,3,5-tris(N-(p-tert.-butylphenyl)-N-(1-naphthyl)amino)- benzene. The yield was 62%.

Elemental analysis (%):

	C	H	N
Calculated:	88.25	7.07	4.68
Measured:	88.23	7.18	4.65

Mass analysis: $M^{+}=897$

Infrared absorption spectrum is shown in Fig. 5.

Differential scanning calorimetry (DSC):

About 5mg of 1,3,5-tris(N-(p-tert.-butylphenyl)-N-(1-naphthyl)amino)benzene was weighed as a sample, and it was melted in a differential scanning calorimetric device and cooled to room temperature at a rate of 50℃ per minute. The sample did not crystallized, but it became amorphous glass. Subsequently, the thermal characteristics of the sample were measured by heating at a rate of 5℃ per minute by using an aluminum plate as a reference. As the DSC chart is shown in Fig. 6, the compound has a glass transition temperature (Tg) of 118 ℃ and a crystallization temperature (Tc) of 170℃.

Cyclic voltammetry (CV):

1,3,5-tris(N-(p-tert.-butylphenyl)-N-(1-naphthyl)amino)-benzene was dissolved in dichloromethane and the solution was arranged at a concentration of 10^{-3} M. The oxidation reduction characteristics of the sample were measured using tetrabutylammonium perchlorate ($(n\text{-}C_4H_9)_4NClO_4$ (0.1M)) as a supporting electrolyte and Ag/Ag^{+} as a reference electrode at a scan speed of 10mV/s. As the CV chart is shown in Fig. 7, the compound has an oxidation potential of 0.6V (vs. Ag/Ag^{+}). It was found that the compound had reversibility in oxidation reduction process after 50 times measurements, indicating that the compound is suitably used as organic positive hole transport agents.

Example 3

(Synthesis of 1,3,5-tris(p-tolylamino)benzene)

11.8 g of phloroglucinol, 50 g of p-toluidine and 0.5 g of iodine were placed in a 300 mL capacity three necked flask and the reaction was carried out at a temperature of 150℃ for 15 hours with stirring under a nitrogen atmosphere. After the reaction, the resultant reaction mixture was washed with methanol, hexane and methanol in this order, followed by drying to provide 31.9 g of the desired 1,3,5-tris(p-tolylamino)benzene as slightly reddish solid. The yield was 86.5%.

(Synthesis of 1,3,5-tris(N-(p-methylphenyl)-N-(4-biphenylyl)-amino)benzene (p-MTPBAB))

2.0 g of 1,3,5-tris(p-tolylamino)benzene, 7.0 g of 4-iodo-biphenyl, 6.9 g of potassium carbonate, 1.0g of copper powder, 0.7 g of 18-crown-6 (or 1,4,7,10,13,16-hexaoxacyclooctadecane) and 15 mL of mesitylene were placed in a 100 mL capacity glass flask and the reaction was carried out at a temperature of 170℃ for 15 hours under a nitrogen atmosphere. After the reaction, the resultant reaction mixture was extracted with toluene and the toluene solution was subjected to silica gel chromatography to fractionate the reaction product. The reaction product was then purified by recrystallization and then by sublimation to provide 2.2 g of the desired 1,3,5-tris(N-(p-methylphenyl)-N-(4-biphenylyl)amino)-benzene (p-MTPBAB). The yield was 16%.

Elemental analysis (%):

	C	H	N
Calculated:	89.07	5.91	5.03
Measured:	88.87	6.09	4.95

Mass analysis: M^{+}=849

Infrared absorption spectrum is shown in Fig. 8.

Differential scanning calorimetry (DSC):

About 5mg of p-MTPBAB was weighed as a sample, and it was melted in a differential scanning calorimetric device and cooled to room temperature at a rate of 50℃ per minute. The sample did not crystallized, but it became amorphous glass. Subsequently, the thermal characteristics of the sample were

measured by heating at a rate of 5℃ per minute by using an aluminum plate as a reference. As the DSC chart is shown in Fig. 9, the compound has a glass transition temperature (Tg) of 98℃ and a crystallization temperature (Tc) of 145℃.

Cyclic voltammetry (CV):

p-MTPBAB was dissolved in dichloromethane and the solution was arranged at a concentration of 10^{-3} M. The oxidation reduction characteristics of the sample were measured using tetrabutylammonium perchlorate ($(n\text{-}C_4H_9)_4NClO_4$ (0.1M)) as a supporting electrolyte and Ag/Ag^+ as a reference electrode at a scan speed of 50mV/s. As the CV chart is shown in Fig. 10, the compound has an oxidation potential of 0.6V (vs. Ag/Ag^+). It was found that the compound had reversibility in oxidation reduction process after 50 times measurements, indicating that the compound is suitably used as organic positive hole transport agents.

Fluorescence spectrum:

A deposition film (an amorphous film) 500Å thick was prepared using a vacuum deposition apparatus, and the film was subjected to measurement of fluorescence spectrum using excitation light of a wavelength of 320 nm. As the spectrum is shown in Fig. 11, the compound has an emission peak at 415.0 nm.

Industrial Applicability of the Invention

The invention provides novel 1,3,5-tris(arylamino)-benzenes. They have oxidation potentials in the range of about 0.5-0.6V and an excellent reversibility in oxidation-reduction process, as well as high glass transition temperatures and excellent heat resistance, and hence they readily form amorphous film useful as organic semiconductors by a coating method or a vacuum deposition method. In addition, the 1,3,5-tris-(arylamino)benzenes of the invention are capable of forming amorphous film by themselves at normal temperatures or higher so that they find wide applications as organic amorphous materials

in a variety of fields, such as electric charge transport agents in electrophotography or organic semiconductors in solar batteries.